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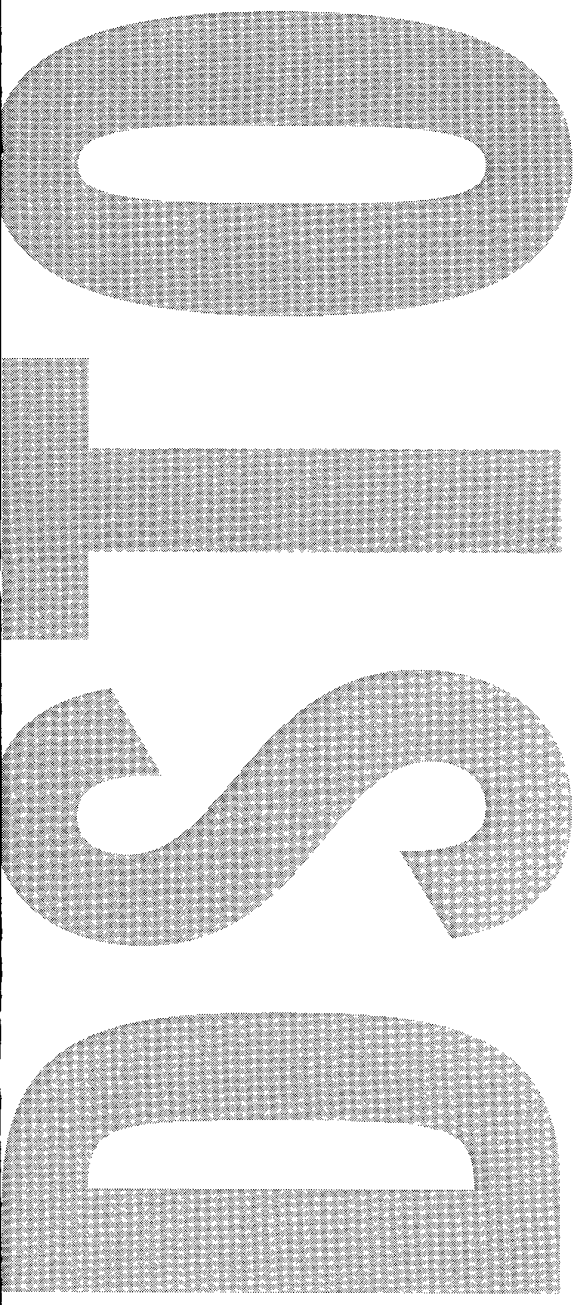

Establishing Measures of Effectiveness for Command and Control: A Systems Engineering Perspective

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ABSTRACT

Formulating Measures of Effectiveness (MOE) for complex socio-technical systems is a difficult task. Systems such as these only become purposeful when they are integrated as part of a parent system. Without this parent system they are purposive and are unable to perform a mission. The MOEs of these component systems are tightly linked to the contribution they can make to the achievement of the parent system's mission. In military operations, the purposeful system is the result of the synergy generated by the component systems that constitute the force assigned to the commander to accomplish a mission. These components combine to provide the emergent properties necessary to satisfy the need and their individual effectiveness is assessed on the contribution they make to the parent system. An essential component of this purposeful system is Command and Control (C2) but it is difficult to separate the contribution that C2 makes to its parent system from those made by other component sub-systems or to treat C2 as an isolated system. Because of this, the formulation of MOEs for C2, and for similar systems in other areas, is a difficult task. It is possible that the behavioural or 'soft' sciences will offer a solution

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Executive Summary

This General Document is an adaptation of a paper to be published by 'Systems Engineering, The Journal of The International Council of Systems Engineering'. Publication is expected in the USA in the first half of 2001.

This document reports on the progress of research into the problems associated with establishing measures for Command and Control (C2). It indicates the importance of making a distinction between effectiveness and performance when assessing C2 systems and in considering the relationship of C2 with its associated military force. There is evidence that effectiveness should be considered as a 'top down' issue, that performance is a 'bottom up' issue, and that C2 is not a 'system' in the manner that systems are described in the emerging discipline of systems thinking.

From a discussion of the nature of Measures of Effectiveness (MOEs), and the distinction between them and Measures of Performance (MOPs), it is established that MOEs are appropriate measures for purposeful systems. The nature of C2 as both a process and a collection of component systems is discussed, as is the purpose of C2. From this it is shown that C2 cannot be isolated from the military force of which it is a part and that its only purpose is to contribute to the success of this force's mission. The difficulty of seeking to establish the effectiveness of C2, as against establishing the level of performance of component elements, is demonstrated as being caused by not recognising that C2 only has existence within the structure of a military force. To establish the contribution of C2 to a force's mission, a holistic approach is necessary where an analysis of the contribution of all elements of the force structure is made. From this, the individual contribution to mission success by the elements making up the C2 'system' may be identified. The behavioural sciences offer a means for conducting such analyses.

The application of systems thinking, especially when developed as a result of further research, will provide a basis for a rigorous approach to the assessing of the contribution that C2 makes to the success of a military mission. The distinction made between effectiveness and performance shows that effectiveness can only be measured against the accomplishment of the mission. This is in contrast to the attempts made to prove the effectiveness of particular groupings of processes and technology by the reductionist approach of considering C2 as something that can be viewed in isolation. Adoption of an holistic view, as an alternative, offers an opportunity to develop rigorous methods of evaluation for C2 .

Contents

1. Introduction

Command and Control (C2) systems are the tools employed by military commanders to manage the forces assigned to them in accomplishing an operational mission. They are an integral and essential part of any commander's assigned force encompassing all functions within the force. Their importance warrants the continual monitoring of new technology in order to ascertain any advantages it may offer in its application to C2. The costs and risks involved are considerable and there is a requirement for a rigorous Test and Evaluation (T&E) programme to minimise these risks. A necessary precursor to any such T&E programme is a set of Measures of Effectiveness (MOE) that is able to provide a guide as to what must be tested to ensure that the C2 system will do the job required of it.

The task of formulating MOEs for C2 systems is acknowledged as being difficult. A symptom of this is seen when discussion of MOEs for C2 amongst practitioners soon moves from issues of effectiveness to those of performance. This report offers an explanation as to why this is so. It will establish what is meant by MOEs, what is a need, and what C2 means. It will examine the important distinction to be drawn between purposeful and purposive systems and how C2 can be one or the other depending on how it is observed. From this will be drawn the reasons why MOEs for C2 are so difficult to be formulated.

While the emphasis is on military systems, there is no reason why the argument cannot be adapted for any managerial system. The nature of C2 is common to situations to be met in commercial and service institutions and not just the military. The report is written in the belief that articulating the nature of the problem is a first step to solving it.

2. What are Measures of Effectiveness?

2.1 Essential for evaluation

MOEs are an essential part of systems engineering, and are referred to in documents such as IEEE Std 1220-1994 and EIA/IS-632. They are a tool designed to help establish if a system, when developed as a solution to a problem, performs the mission required of it by a stakeholder. As far as the stakeholder is concerned, the solution is merely a means to an end. This is in effect saying that the stakeholder is considering factors external to the solution when making a choice as to which solutions will meet the need. MOEs form the basis of a T&E programme for candidate solutions and so are an essential part of any rigorous evaluation programme.

2.2 A definition

Yet, despite its importance and frequent reference in the literature, there is no universal definition for the term and there is much confusion with the manner in which it is used. The giving of the same meanings to similar terms exacerbates this. Sproles[1998] has suggested a definition and a methodology for the use of MOEs as a basis for standard usage. This was achieved by drawing upon the thread of agreement that can be found in the literature when the term is used. The suggested definition is that MOEs are

'...standards against which the capability of a solution to meet the needs of a problem may be judged. The standards are specific properties that any potential solution must exhibit to some extent. MOEs are independent of any solution and do not specify performance of criteria.'

2.3 An important distinction

Characteristics of MOEs include the ability that they can be tested and perhaps be able to be quantified in some manner. This latter characteristic does not preclude the use of MOEs that will ultimately rely on subjective assessment or are qualitative in nature. However, an MOE is a statement and is not the figure obtained as a result of any measurement process. A distinction must be made between MOEs and Measures of Performance (MOP). A MOE views the solution from the stakeholder's viewpoint and so is an external view of the solution. MOPs on the other hand view the solution from the solution developer's viewpoint and are therefore an internal view. This distinction is discussed in detail in Sproles(a) (2000, pp 50-58)). MOEs are concerned with how well the solution performs the intended purpose while MOPs look at how well the solution does what it actually does and a parallel can be drawn with the distinction between effectiveness and efficiency or accuracy and precision.

2.4 Stakeholders

The term 'stakeholder' is used in a generic sense, as there may be many stakeholders with an interest in a solution to a problem. Some stakeholders may be the customer or user of the system while others may have no direct interest in the solution *per se* other than that it may have some form of impact on their interests. In human society, people's interests overlap and it is this overlap that often brings about conflict and the need to include disparate groups in the selection of a solution. The variety of interests that contribute to the preparation of environmental impact statements is just one instance of this. Different stakeholders will have differing needs and therefore will have formulated their own criteria as a basis for deciding if some solution is acceptable to their interests. Stevens [1998: 22] draws a distinction between the requirements of the user and these other stakeholder's. Of all the stakeholders, there is one group whose need defines the function of any proposed solution. For example, a mining company may want to mine a new ore deposit. While an environmental impact statement may address the needs of all the stakeholders, it is fundamental that the final solution must at least result in, say, a profitable mining operation. If satisfying the

requirements of other stakeholders prevents this, then the mine may not be developed. 'To establish if a candidate solution to a need successfully meets that need, a stakeholder must first establish if it is functionally successful' [Sproles (a), 2000: 53]. MOEs are concerned with these functional requirements. They relate to the need of those stakeholders whose concern is the function of the solution and the other requirements, '...important as they are, they do not dictate the function of the solution' [Sproles(a), 2000: 53]. The needs of the other stakeholders may represent constraints on the choice of a solution, but the solution chosen must still satisfy the needs of the stakeholder who identified the need. For the purpose of this report, a stakeholder is one who is responsible for establishing if a solution meets the functional elements of the need.

Therefore, when formulating an MOE, it is important to consider the viewpoint from which the MOE is being formulated. The formulation of MOEs is a cognitive process using those functional issues that the stakeholder considers critical to the acceptance or otherwise of the solution. These are variously called Critical Operational Issues (COI) or 'show stoppers' and represent those issues which, if not successfully addressed, will make the solution unacceptable on functional grounds.

2.5 The engine of Test and Evaluation

While T&E may be used to assess the 'quality and goodness' of an entity, that which constitutes 'quality and goodness' needs to be defined before T&E can commence. MOEs fulfil this function and so serve to act as the 'engine' of T&E. It would be pointless to hand an item to the test agency and say 'Test and evaluate this for me to see if it meets my needs' without also providing some indication as to the goal of the test. The test agency will need to know details about the stakeholder's need; it will need to know what the item must be able to achieve in order to satisfy the stakeholder's need; and it needs to know how the stakeholder will judge success. The stakeholder provides the test agency with this information in the form of MOEs that can be tested and so it is the MOEs that establish the properties to establish 'goodness'. 'MOEs...form the basis for the operational evaluation which, in turn, shapes the operational tests' [DoD Test and Evaluation Process, 1994:3]. When referring to testing, the US Navy T&E agency states that the tests are '...designed to help us determine the things we need to know about the system – quantitative things included in the various MOEs...'. It also noted that the process of selecting MOEs is to determine '...what the evaluator needs to know to adequately test and evaluate the suitability COIs [Test Directors Guide, 1996: 6- 14].

3. Defining 'Need'

Reference has been made to the stakeholder's need but the word 'need' has many meanings in the English language. In this report it is taken as referring to a goal or mission or the end to be achieved as distinct from the means to that end. 'Goal' itself is a word often requiring a clarification of its meaning. One useful meaning is given by Preece et al. [1994: 411] who refer to a goal as a desired state of a system that '...must be described at a particular level of abstraction', which is the meaning intended for 'need' in the context of this report. However a distinction must be made between the goal and the means of achieving the goal. The definition being sought is one that emphasises what is wanted rather than what must be done to satisfy a customer or stakeholder. Drucker [1977: 57] points out that a customer buys value, which he calls 'utility', and not a product. The customer is buying utility or '...what a product or service does for him or her' so 'need' must express the utility required and not the product that may satisfy this need. It is possible that several products may be able to satisfy the customer's requirement for utility; which of the contending products is chosen is a matter for the customer. Preece et al. [1994: 411] follows a similar line of reasoning. They note that goals are achieved using some form of device(s) and that once a goal has been formulated, a person will select the device(s) necessary to achieve that goal. In other words, the customer determines what Drucker [1977] calls 'utility' and then seeks the means to achieve this 'utility'. 'Need' therefore is taken to refer to an abstract entity in the sense that this entity is not '...associated with a specific instance' [Webster]. This is opposed to the tangible or the means to the end, which can be described as '...capable of being precisely identified and capable of being appraised...'[Webster]. The intangible is utility; the tangible is product(s) of some form.

A further distinction can be drawn between the meaning of 'goal' and 'end' and it can be argued that social systems are not goal seeking so much as 'relationship maintaining' [Checkland, 1981: 165]. Acceptance of this viewpoint necessitates further refining of the definition. In their thesaurus, Webster notes that goal '...means what one intends to accomplish or attain', while an end '...stresses the intended effect of action often in distinction or contrast to the action or means as such'. In placing a meaning on 'need', it is felt that the nuance provided by the latter definition may be more appropriate than calling a 'need' a goal. Therefore, for the purpose of this report, a 'need' refers to the desired end and is separate from whatever means may be available to meet this end.

4. Purposeful and Purposive

Checkland [1981: 119] notes that 'Man as a designer is a teleological being, able to create means of enabling ends to be pursued...'. He makes a distinction between such systems designed by humans and natural systems and further breaks the designed

systems into what he calls 'purposeful' and 'purposive' systems. A purposive system '...exists implacably' and is given the meaning of 'serving a purpose' while a purposeful system involves conscious human action. A designed system becomes purposeful when it becomes part of a 'human activity system' [Checkland, 1981: 115]. The example is provided of a watch escapement being purposive, while telling the time is purposeful as it serves a human purpose and involves humans. When Drucker [1977: 432] states that 'The most beautifully designed machine is still only so much scrap metal until it has utility for the customer' he is illustrating the difference between purposeful and purposive systems. A ship or an aeroplane would qualify as such 'beautifully designed machines' but by themselves they will lie dockside or stand on a runway and do nothing except obey the second law of thermodynamics and other natural laws. It is only when they are combined with a crew and mission as well as other elements such as payloads and refuelling systems that they can provide utility to a customer or stakeholder. Products by themselves seem to serve no purpose; they can only justify their existence by being part of a system meeting a need. A hammer by itself is useless; combine it with a carpenter, other tools such as a saw, some nails or glue, pieces of timber, and a plan and it becomes a component in a system that provides, say, comfort for humans ie. it becomes a component of a furniture production system.

Preece [1994: 411] suggests that there is a nexus between humans and goals when they describe a goal as '...a state of a system that the human wishes to achieve...'. Mitchell [1986: 10-11] discusses how people join together in organisations in order to attain physical, personal, or economic advantages. This comes about because humans believe that this is the best way to reach goals and, as a consequence, "...organisations are designed and exist to facilitate the attainment of objectives". Hitchins (pers.com., April 2000] suggests that humans may be a necessary and integral component of purposeful systems and it is an idea that may well be true. Checkland [1981] at least implies that this is so in his discussions of human activity systems.

5. Measures of Effectiveness and Purposeful systems

The successful meeting of a need requires a purposeful system as only such a system provides utility to a human. Stevens et al., [1998: 5] state that the correct response to a user's need is a full operational capability and that the user does not want a product but a complete service. A product is purposive whereas the complete capability or service is purposeful. Needs are met by purposeful and not purposive systems. MOEs have been defined as the standards by which it can be judged whether or not a solution has satisfied a need and so are satisfied by purposeful systems. The appropriate measures for purposive systems would be MOPs.

6. Contribution as a basis for Measures of Effectiveness

Systems do not necessarily exist by themselves but can exist within larger systems. '...it is possible to couple large systems together to create large meta-systems, or "systems of systems". These meta-systems fulfil functions greater than the set of coupled systems from which they are built' [Stevens et al., 1998: 302] while Hitchins [1992] introduces the idea of a system or systems being contained within a containing system.

Hitchins [1992, chap 4-5] discusses the relationship between effectiveness and contribution. Effectiveness is described as how well something does something and this is the definition used in this report. Contribution is then described as what a contained system contributes to its containing system, and Hitchins [1992] sees this as being a more useful measure than effectiveness. There seems no reason not to get the benefit of both ideas by combining them and saying that effectiveness is how well something does its job and that its job, in turn, is to contribute to the effectiveness of its containing system. This is akin to saying that, when formulating MOEs, the MOE should reflect the desire to win the war as well as to win the battle.

7. What is Command and Control?

7.1 Origin of phrase 'Command and Control'

Ashworth [1987: 36] refers to the phrase 'Command and Control' as 'a composite word' in order to stress that C2 is not a combination of the separate terms of 'command' and 'control' with one being subordinated to the other. He traces the origin of the term to World War II when it was initially applied to Combined[1] and Joint operations where command, that is authority and responsibility, had to cross national and organisation boundaries. On occasions, there was confusion and misunderstandings when commanders realised that they did not have the full command authority and associated responsibility that they had come to expect in single service commands. It was in this context that McCarthy [1959: 15] used the term 'command and control' when referring to the 23 December 1941 conference between British and US political and military leaders. He says, 'Among the most important results of the December conferences was agreement between Britain and America regarding the machinery to be set up for the strategical command and control of their military resources'.

[1] Combined operations refer to the use of the forces of different nations and is different from Joint operations which refer to operations using the various services of the one nation. The Combined Bomber Offensive (CBO) was a combined operation as it used the Air Forces of the USA and UK. The Falklands campaign was a Joint operation because the British navy, army, air force and marines acted together under one commander.

McCarthy explains that this was a '...principle of unity of command' with its first expression in the American, British, Dutch, Australian Command (ABDACOM) in what is now Indonesia. Brittanica [1959: 277] describes how the system of the Combined Chiefs of Staff and Supreme Commanders achieved the controlling organisations '...needed to encompass both interservice and inter-Allied coordination' and solved the problem of '...coordination and direction'.

7.2 Command and Control as a means to an end

Ashworth [1987: 34] notes how C2 has, over the years, '...acquired additional meaning, gathering into its fold such things as communications, computers, and intelligence, and grandiose titles like C3I'. In developing an explanation of why it has proved difficult to formulate MOEs for C2, it is useful to examine the 'additional meaning' given to C2 and determine what C2 is seen as encompassing at this time.

Many definitions of C2 to be found in the literature see the 'command and control' function as being synonymous with the mechanics by which a commander exercises command authority. An indication of this can be seen in some of the terminology, or 'grandiose titles' in Ashworth's [1987] view, associated with C2. Ryan [1997: 7] provides some examples commonly found in the literature. All these acronyms place emphasis on some part(s) of the components that make up C2 reflecting an emphasis on means at the expense of the end sought:
C3 -- command, control and communications;
CIS -- communications and information systems;
C3I -- command, control, communications and intelligence;
C4I -- command, control, communications, computers, and intelligence; and
C4ISR -- command, control, communications, computers, intelligence, surveillance, and reconnaissance.

Prior to the 1970s, the term C2 was rarely used and instead one spoke of the 'staff' for it was the staff who supported the commander in both the operational and administrative functions of command. Early commanders such as Alexander and Caesar did not have staffs but did all their work themselves. Even Napoleon commanded his great armies with only the assistance of a few runners [Brittanica, 1959], and in the 1870's Moltke commanded a force of one million using a General Staff of only 70 officers [Van Crevald, 1985:7]. However even these great commanders needed communication systems even if they were only runners. The 'grandiose titles' given to C2 do serve a purpose in stressing that the system comprises more than just the staff but includes a collection of other systems such as communications, intelligence sensors, procedures, etc.

Some current definitions refer to C2 as a system and indicate that C2 is a tool to be used in conjunction with other tools such as combat and support units. The US Navy goes even further when it states that C2 "...is the tool the naval commander uses to cope with the uncertainty of combat..." [NDP6, 1995, i]. The same document [NDP6

1995: 8] states that 'A commander is connected to his subordinate commanders by a command and control system...' and also draws the analogy that C2 is like the sensory nervous system of the body while the commander is the brain. The brain (commander) uses the nervous system to receive information and to disseminate orders.

Other definitions describe instead the purpose of C2, such as MCDP6 [1996] which states that C2 is '...how we can reach effective military decisions and implement effective military actions faster than an adversary'. Another such definition is provided by FM 17-95 [1996] which states that the '... purpose of the command and control system is to implement the commander's will in pursuit of the objective'. The Australian definition [ADFP1, 1993], which is nearly identical to the US definition given in Joint Publication 1-02 [JP 1-02], combines both approaches when it says that:

Command and control is the process of and the means for the exercise of authority and direction by a properly designated commander over assigned forces for the accomplishment of the commander's mission. Command and control functions are performed through an arrangement of personnel, equipment, communications facilities and procedures that are employed by a commander in planning, directing coordinating and controlling his forces and operations.

Dennis et al. [1995: 169] emphasises the difference between 'command' and 'control' and that the words are not intended to be synonymous. A distinction is made between the meaning of the term when applied at the operational level and at the higher levels of military organisations. They note that current American usage '...refines these terms somewhat so that control encompasses the planning, direction, coordination and control of forces and operations in the accomplishment of the mission'. The value of the explanation is lost somewhat by defining 'control' in terms of 'control'.

In these definitions, C2 is sometimes being used as either a noun phrase or a verb phrase, and sometimes as both. As a verb phrase, it denotes what C2 does. It '... describes a process ... a collection of related activities' [MCPD6, 1996]. These activities include the collection and analysis of information; making of decisions; organising resources; planning; communicating instructions and information; coordinating; monitoring results; and supervision. As a noun phrase, it describes how C2 achieves the process. It '... describes a system - an arrangement of different elements that interact to produce effective and harmonious actions' [MCPD6, 1996]. These elements are people; information; and those items that provide the support structure.

7.3 Command and Control as a process

C2 as a process is illustrated by the range of activities in what Ryan [1997: 6] refers to as the Decision Cycle, Boyd Cycle[2] or the OODA Loop where OODA is an acronym for

[2] Named after a former USAF officer, Col. John Boyd in 'An organic design for Command and Control', "A discourse on winning and losing". Unpublished lecture notes, August 1987 (NDP6, 1995, p. 18)

Observation, Orientation (understanding), Decision and Action. MCDP6 [1996] illustrates this loop as depicted in Figure 1

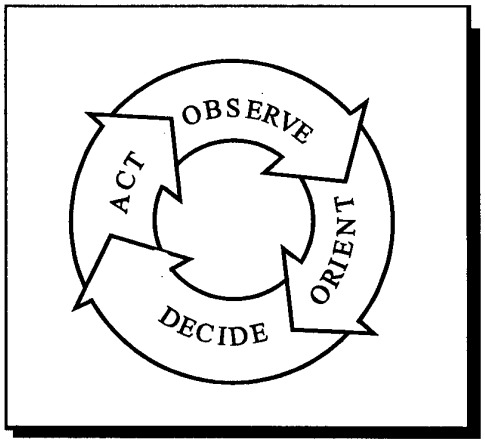

Figure 1: The OODA loop

A process is a 'a series of actions or operations conducing to an end'; [Webster]. C2, as a process, changes ideas into action and is a cyclic process. During the course of a military operation, a commander makes decisions, gives instructions, observes the results, and makes further decisions amending or altering the previous decisions. The function of observing results and amending or altering the previous decisions is the function of 'controlling' which Urwick [1961: 97] describes as a method to keep informed as to the result of plans and orders.

A commander uses the various facilities available, such as sensors and situation reports, to Observe by collecting data about the enemy and the commander's own forces. This data is then correlated in order to provide Orientation, or as Ryan [1997] has noted, to understand. In fact, orientation is more the gaining of a mental picture of the situation. It is not necessarily the understanding of the situation if we take the view that knowledge is being aware of 'what is happening' and understanding is being aware of 'why it is happening'. Understanding is best seen in that elusive ability of great generals, such as Montgomery and Rommel, to see into the 'mind of the enemy'.

After orientation, the commander is able to Decide to take a course of action and to disseminate a plan. When the plan is put into Action, the commander is now able to Observe the results and to bring these results into line with the desired results. In effect, the loop has started over again. During this process, the commander is afflicted by 'the fog of war', or the 'friction of war', caused by the uncertainties and vagaries of conflict and the fact that there are humans in the loop.

7.4 Command and Control as a system

Van Crevald [1985:262] notes that 'Command systems...consist of organisations, procedures, and technical means; command itself is a process that goes on...within the system.' This process and the system of C2 are inextricably intermeshed. Whereas a process is 'A series of actions, changes, or functions that bring about an end or result'[Webster] , it is the system that brings this process about by providing the means to realise it. The stakeholders specify the 'technical means' in order to be able to execute the process. These technical means can be tested using quantitative data gained from objective testing. It is this that causes discussion about C2 systems to shift from MOEs to MOPs as discussed in the Introduction to this report.

The C2 'technical means' can be depicted as an organisation comprising the three elements of people, information and support as shown in Figure 2. People comprise all those who '...gather information, make decisions, take action, communicate, and cooperate with one another in the accomplishment of a common goal' [MCPD 6, 1996]. Information is the fuel for the C2 process and it is the aim of the commander to collect and process information at a faster rate than the enemy in the pursuit of reducing uncertainty. Support comprises the people, equipment, facilities and procedures that actually collect, process and disseminates the information to the commanders at the various levels and their subordinates.

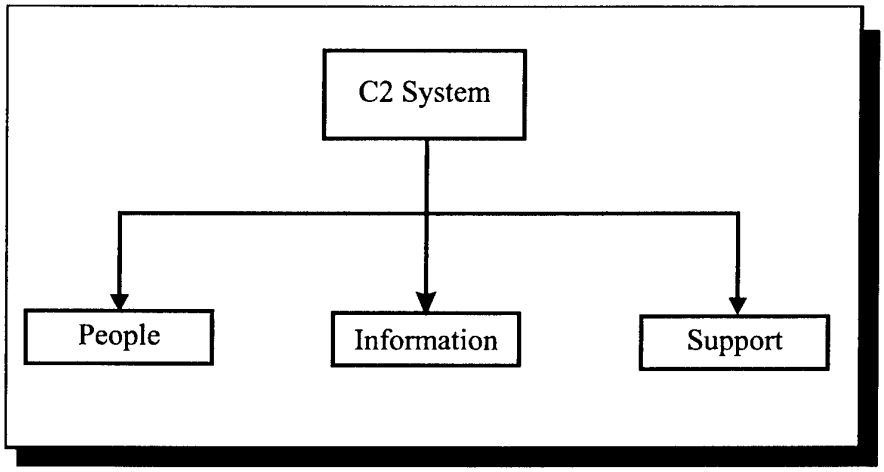

Figure 2: Outline of the C2 system

From the definitions it can be seen that the 'what' of C2 is '...planning, directing coordinating and controlling'. The 'how' is '...an arrangement of personnel, equipment, communications facilities and procedures that are employed by a commander'. The 'what' of C2 is achieved by a process -- the 'how' by the technical means or what is commonly referred to as C3I etc.

8. What does Command and Control do?

Hitchins [1997] states that C2 is the management of conflict where management [Harper Collins, 1995: 377] is '...the process of organising and directing human and physical resource within an organisation so as to meet defined objectives'. This is achieved through planning; control; coordination; and motivation. This is supported by an analysis of the definitions of C2 previously provided:
'...how we can reach effective military decisions and implement effective military actions faster than an adversary' [MCDP6 1996];
'...the exercise of authority and direction by a properly designated commander over assigned forces for the accomplishment of the commander's mission' [ADFP1, 1993];
C2 '...allows a commander to make effective decisions and direct the successful execution of military operations' [NDP6, 1995];
"...planning, directing coordinating and controlling his forces and operations' ADFP1, 1993; and
'...to implement the commander's will in pursuit of the objective' [FM 17-95, 1996].

This need for management systems has been the same for military commanders from Alexander through Caesar, Marlborough, Napoleon and Wellington, Grant, Monash, to Schwarzkopf and Cosgrove. The only significant difference is the technology of the solutions available to them to meet that need. As military forces became larger and more complex, there was an increasing requirement to provide assistance to the commander in managing the force so as to accomplish the mission. In the mid 19th century, European nations developed C2 systems built around highly trained military staffs using whatever technology was available at the time. These military staffs have developed into today's C2 systems but, while the means have changed radically, the need for the commanders to be able to manage their force has always been the same!

Having been given a force and a mission, the commander has a need for a system to enable this force to be managed as it prepares for and undertakes its mission. Managing covers concepts such as tempo, situational awareness, exercise of authority, planning, direction, coordination, control, etc. as referred to in the definitions. That such a need exists and that humans address such needs by setting up organisations such as a C2 system is as old as mankind.

9. Who is the stakeholder?

Once a commander is given a mission, C2 becomes '...fundamentally the business of the commander' [MCDP 6,1996]. The commander is the focus of the C2 process and system because 'The commander drives the command and control process and has final responsibility and accountability for success of the mission'. 'At any level, the key individual in the command and control system is the commander who has the final responsibility for success' [NDP6, 1995: 8]. Having been given '...final responsibility

and accountability for success of the mission', the commander is therefore the stakeholder in whatever C2 system is provided and the requirements and MOEs will be written with this in mind. There will be others who have an interest in a C2 system such as the government who must finance it; industry who must develop it; etc however it is the commander who determines the intended function of the system.

9.1 The containing system

MLW One 1-1 [1992, 2.37] states that the ultimate aim of military operations is victory and that 'selection and maintenance of the aim' is the first principle of war. Thus, while a commander has a need to be able to manage the resources allocated to him, it would be difficult to argue that this was the end state desired by the commander let alone an end state more important than achieving the assigned mission. The C2 or staff system is a means to an end and the end is the mission.

In order to be able to achieve the mission, the commander is assigned a force. This force is a purposeful system in the form of a synergistic combination of sub-systems brought together with the clear intent of achieving the mission. 'The outcomes of battle emerge from the interaction of the many parts of a complex, chaotic and dynamic system [LWD1, 1998: 2-6]. C2 is one such component system. 'Applying the art of war...requires comprehensive staff procedures, intuition, judgment, and an understanding of the relationship between a wide range of factors that bring extraordinary complexity to every situation' [LWD1, 1998: 2-6]. C2 is therefore a contained system in the meta-system needed to achieve the commander's mission. As such, C2 must need to be able to make a contribution to that meta-system and will be judged on that contribution.

10. Contribution

There are ample examples in the literature to show that C2 systems have contributed to mission success in the past. Air Chief Marshall Sir Basil Embry, former Commander-in-Chief Allied Air Forces, Central Europe when praising the contribution made by the staff arrangements of the Royal Air Force immediately prior to World War II, noted the importance of the managerial aspect and observed that as a result:
'...the Royal Air Force, in the early years of the war, was able single-handed not only to match up to the combined strength of the German and Italian Air Forces but to inflict on them decisive defeat' [Embry, 1958: 79]. General Sir Brian Horrocks who commanded the British XXX Corps in Europe after D Day was once asked by General Montgomery if given the choice between six divisions in his Corps or five divisions and a first class communications system, which would he prefer. Horrocks opted for the latter as '...it is quite impossible to fight a modern battle without first-class communications' [Horrocks, 1977: 29]. Here Horrocks has indicated that he considers a first rate communications system will make a greater contribution to the outcome of the battle than an extra division. The basis of choice is on the success of the mission – the

fighting of the battle – rather than on the merits or otherwise of communications *per se*. If another similar rhetorical question was posed seeking his choice between a different set of component systems, he may well have opted for a different combination. But in all instances the choice would be based on the contribution to the outcome of the battle or mission.

C2 '...by itself will not drive home a single attack...it will not destroy a single enemy target' but it does '...help commanders make the most of what they have – people, information, material ...and time' [MCDP6: 1]. The view expressed in 1917 by the Chief of Staff for Second British Army that 'The staff are servants of the troops' [Smithers, 1973: 163] gives further credence to the notion that C2 is a means to an end and not an end in itself.

11. The Difficult Task of Formulating Measures of Effectiveness

11.1 Command and Control as a complex system

Jackson and Keys [1984:475] make a distinction between complex and simple systems. They note the small size of the components and the regular interaction between the components for simple systems as opposed to the large number of components and high interrelationships of complex systems. Checkland [1981] describes systems as falling into the four classes of natural, designed, designed abstract, or human activity systems. A term often used, in a similar fashion to Checkland's human activity system, is 'socio-technical systems'. Kline [1995: 60] illustrates this when he defines them as linking humans with hardware or tools so as to perform tasks that people want done. Socio-technical or human activity systems generally fall into the category of complex systems, while designed systems are usually considered not to be complex.

C2 systems are socio-technical systems built up of groups of people and equipment as illustrated in Figure 2. As such, they '...pose difficult problems because they are often only partially observable, probabilistic, open...' [Jackson, 1984: 476]. They indicate several implications when dealing with such complex systems, two of which have particular relevance to the problem of why it is difficult to formulate MOEs for C2 systems. They have been adapted to demonstrate that the contribution that C2 must make to the meta-system, or purposeful system, assembled to achieve the mission cannot be readily identified; and that C2 systems cannot be isolated.

11.2 Contribution cannot be identified

The MOEs for C2 must be based on the contribution C2 makes to the meta-system represented by the purposeful system that is the commander's force. On rare occasions this contribution, or the lack of contribution, is so obvious that it can be identified. The

withdrawal from the Gallipoli Peninsula in December 1915 is often cited as '...a model of precision and clear thinking' [Bean, 1968: 178] where C2 contributed significantly to the success of the operation. The 1st British Airborne Division's operations at Arnhem in 1944 are, on the other hand, an example of how a C2 system failed to make a positive contribution to the battle. Radio communications broke down between all levels making it impossible for the commander to control his division. The commander himself '...had been absent and lacking control of the battle in its most crucial period, for almost 39 hours'[Ryan, 1974: 355].

Instances where the contribution is so obvious are exceptional for the contribution of C2 is generally lost amongst the synergy that occurs when all the components of a complex system combine to provide the emergent properties of the meta-system. If the contribution that C2 makes was always as obvious as the above examples then an MOE such as 'Contribution to mission accomplishment' would be simple to establish and, more importantly, to test. But the contribution is rarely so obvious and formulating an MOE to capture qualities that will indicate contribution is difficult. This is more so when it is remembered that the MOE must be capable of being measured and that an MOE that cannot be measured is of no use.

The C2 system exists to help the commander in the accomplishment of the mission, but the commander is ultimately only interested in the emergent property of the purposeful system that is his force and its ability to achieve the mission. That is the only job that can always be measured for effectiveness. The assistance provided by the C2 system is only of interest so long as it makes a contribution to mission achievement. The stakeholder is seeking utility and this is most obvious in an examination of whether the mission was accomplished or not. That this is so is evident in an analysis of the literature. Military history texts speak at length about the mission and whether it was achieved or not and even why this may have occurred. Only on rare occasions will aspects of C2 be discussed such as in the works of Van Crevald [1985] or when Horrocks [1958] gave a cursory outline of the functioning of a corps HQ.

An analogy can be drawn between C2 as a component of the meta-system and the making of a cake. The ingredients, when combined and cooked, lose their individuality and cannot be distinguished one from the other. Hence the expression that 'the proof of the pudding is in the eating'. What contribution does the quality of flour made from a particular variety of wheat make to the satisfaction to be gained by eating the cake? It would probably be difficult or even impossible to ascertain. It is only when some ingredient capable of really standing out is added, such as almonds in a fruitcake, that the contribution can be judged. To continue with the analogy, C2 generally compares with the standard ingredients of the cake making it virtually impossible to formulate MOEs that can isolate qualities that are testable

11.3 Command and Control systems cannot be isolated

Without a commander and the commander's associated force, the best-designed C2 system in the world has no purpose. There is no one to report to; there is no one to receive instructions from and no one to give instruction to; there are no resources to allocate; there is nothing to coordinate; and there is nothing or no one to receive information from. It would exist implacably with its staff and its equipment idly passing time! A C2 system isolated from the commander's purposeful system is as nothing just as the commander's force without a C2 system is also as nothing. C2 cannot be as a singularity because it '...encompasses all military functions and operations, giving them meaning and harmonizing them into a meaningful whole' [MCDP6: 1].

The inability to isolate C2 as a purposeful system in its own right contributes to the difficulty in formulating MOEs. For example, an infantry battalion or a tank regiment can be a purposeful system in its own right and scenarios could be developed enabling MOEs to be formulated and for them to be tested in isolation. The results from such MOEs and tests could be used as the basis for an estimate of their contribution to a meta-system such as the commander's force. Similarly, being able to be isolated, their contribution to the meta-system could be assessed by withdrawing them from the meta-system or replacing them by another component and observing the effect. It is therefore reasonable to have an MOE of 'Contribution to mission achievement' for, say, infantry battalions, as they can be isolated. In theory, this should be able to be applied to C2 by installing different C2 systems into different formations or units and making a comparison of the effect on accomplishing a mission. In practice this is difficult to achieve due to the implications in training, the effect on operational readiness, and cost. It may be possible for the largest military forces to attempt this but it would be beyond the resources of most countries. It is unlikely, for instance, that any modern military force still has the C2 systems of the Vietnam War era in service. This would make it difficult to attempt using the pre computer age C2 systems as a bench mark for the contribution of a new C2 system. Similarly, the rapid evolution of computer systems and their often *ad hoc* utilisation in C2 systems makes it difficult to find any post computer age benchmarks.

It is not possible to isolate a C2 system from its meta-system thus making this type of approach impossible. Without the other systems that make up the purposeful system, there is no job for C2. When looking at a functioning C2 system, it is not possible to say what it has to do only how well it does what it is doing. Such a system cannot be examined from the outside only from the inside. It has no existence in its own right. A C2 system cannot be purposeful in its own right and so, it follows, that a C2 system *per se* is purposive. In its purposive state it cannot, by definition, do a job and so it is not possible to formulate MOEs for it. C2 only becomes purposeful when it is integrated into a meta-system and its change of state is brought about by its ability to make a contribution to the meta-system. This, as has been discussed previously, has its own problems.

11.4 The behavioural sciences contribution

Those associated with the development, implementation, and use of C2 systems would seem to be more familiar with the hard sciences such as mathematics and physics, than with the behavioural or soft sciences such as psychology, anthropology, and sociology. The bias therefore may well be towards the hard sciences when formulating MOEs so that they can be tested by obtaining quantitative data using objective means. However, as a socio-technical system, there should be scope for seeking MOEs better able to be tested by seeking either quantitative or qualitative data from subjective sources. Van Crevald [1985: 262] discusses the absence of quantitative data suitable for statistical analysis and how that data, even if available, would probably fail '...to capture many of...the most important aspects of command'. He indicates that some of these aspects include informal communications within an organisation; the ability to distinguish between relevant and irrelevant information; a commander's mental processes; and body language. The behavioural sciences have great experience in these areas and have developed methods for obtaining data from which conclusions or insights may be drawn. It is an area worthy of further research to confirm that a bias towards the hard sciences exists and to establish the role that the softer sciences may have in formulating MOEs for C2. The contribution that a C2 system makes to the meta-system may be able to be ascertained by discursive means. The Defence Science and Technology Organisation (DSTO), in an evaluation of the impact of the Australian Army's Battlefield Command Support System (BCSS) on the operational capability of a mechanised brigade, have already tried such an approach with some success [Sproles(b), 2000:183-4].

12. Conclusion

The difficulty in formulating suitable MOEs for C2 lies in the difficulty of establishing if the C2 system has or has not made a contribution to the accomplishment of the operational mission. Whatever contribution C2 may make is generally masked by the contribution made by other component systems. Because these contributions are combined to produce an emergent property of the total system, one can rarely be separated from the other. It is only when some gross contribution is made, for better or for worse, that an observer can make such a distinction. As well, it is not possible to treat C2 as a separate entity making techniques available to other systems impossible to utilise. While no solutions have been offered as to a way around this dilemma, it is suggested that the approach taken by the behavioural or soft sciences may warrant investigation. Experience with the BCSS project has indicated that techniques such as focus groups, workshops, and discursive analysis offer worthwhile areas for continued research. Even without a solution to the problem, the establishment of a theoretical basis to explain what is happening shows a path to be followed when working with C2 systems.

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19. ABSTRACT

Formulating Measures of Effectiveness (MOE) for complex socio-technical systems is a difficult task. Systems such as these only become purposeful when they are integrated as part of a parent system. Without this parent system they are purposive and are unable to perform a mission. The MOEs of these component systems are tightly linked to the contribution they can make to the achievement of the parent system's mission. In military operations, the purposeful system is the result of the synergy generated by the component systems that constitute the force assigned to the commander to accomplish a mission. These components combine to provide the emergent properties necessary to satisfy the need and their individual effectiveness is assessed on the contribution they make to the parent system. An essential component of this purposeful system is Command and Control (C2) but it is difficult to separate the contribution that C2 makes to its parent system from those made by other component sub-systems or to treat C2 as an isolated system. Because of this, the formulation of MOEs for C2, and for similar systems in other areas, a difficult task. It is possible that the behavioural or 'soft' sciences will offer a solution

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